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Authors	Stuart D. Allen, and R. W. Hafer
Working Paper Number	1983-014A
Creation Date	January 1983
Citable Link	https://doi.org/10.20955/wp.1983.014
Suggested Citation	Allen, S.D., Hafer, R.W., 1983; The Term Structure of Interest Rates in a Short-Run Money Demand Function: Non-Nested Test Results, Federal Reserve Bank of St. Louis Working Paper 1983-014. URL https://doi.org/10.20955/wp.1983.014

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The Term Structure of Interest Rates in a Short-Run Money Demand Function: Non-Nested Test Results

by
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Research Working Paper
83-014

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We would like to thank Dan Thornton for his helpful discussions on implementing the test procedures, and Jane Mack for her research assistance. The views expressed are the authors' and may not reflect those of their employers. The usual caveat applies.

1. INTRODUCTION

The demand for money literature surveys by Laidler (1977) and Feige and Pearce (1977) note that single interest rate may not adequately capture the opportunity cost of holding money. When one attempts to incorporate more than a few interest rates, however, its well-known that the econometric difficulties that arise -- essentially through the multi-collinearity among the rates -- preclude the usefulness of this approach.

Recent studies circumvent the econometric problems encountered when several rates are used by a research strategy based on the theoretical analysis of Friedman (1977). He suggests that the level, slope and curvature of the term structure of interest rates should be parameterized and included in a money demand function. Based on this insight, Heller and Khan (1979), Khan (1980), Bilson and Hale (1980), Friedman and Schwartz (1982) and Allen and Hafer (1983) have estimated term structure equations and employed the coefficient estimates as opportunity cost variables in a money demand function. With the focus being primarily on the stability properties of the term structure money demand models vis-a-vis a standard specification, the results are inconclusive.

Previous investigations into the validity of competing money demand specifications usually have been carried out by using the classical F-test and examining the statistical properties of the competing models; e.g., stability and out-of-sample forecasting.[1/] In this study, we formally test the statistical importance of incorporating the term structure information relative to either a short- or long-term interest rate using the Davidson and MacKinnon (1981) non-nested test procedure.

The non-nested test procedure is presented in Section 2. The estimation results and the non-nested test findings are presented in Section 3. The forecasting capabilities of the alternative specifications are explored in Section 4. Some concluding remarks appear in Section 5.

2. NON-NESTED TEST PROCEDURES

Davidson and MacKinnon's non-nested test, referred to as the J-test, is suited ideally to our present task. To illustrate the J-test, consider two standard versions of a money demand equation:[2/]

$$(1)\quad \ln (M/P)_t = \alpha_0 + \alpha_1 \ln y_t + \alpha_2 \ln T\ bill_t + \alpha_3 \ln(M/P)_{t-1} + \varepsilon_{1t},$$

$$(2)\quad \ln (M/P)_t = \beta_0 + \beta_1 \ln y_t + \beta_2 \ln Bond_t + \beta_3 \ln(M/P)_{t-1} + \varepsilon_{2t},$$

and a term structure specification:

$$(3)\quad \ln(M/P)_t = \delta_0 + \delta_1 \ln y_t + \delta_2 \gamma_0 + \delta_3 \gamma_1 + \delta_4 \gamma_2 + \delta_5 \gamma_3 + \delta_6 \ln (M/P)_{t-1} + \varepsilon_{3t}$$

where M = nominal money balances (M1),
P = GNP price deflator (1972=100),
y = real GNP ($1972),
T bill = 3-month Treasury bill rate,
Bond = 20-year Government Bond rate,
γ_i (i=0,1,2,3) = term structure parameters, and
ε_i = independent error terms.

The term structure parameters (γ_i) are the estimated coefficients from the following cubic term structure specification:

$$(4)\quad \ln R_{jt} = \gamma_{0t} + \gamma_{1t} \ln T_j + \gamma_{2t} \ln T_j^2 + \gamma_{3t} \ln T_j^3 + \varepsilon_{4t}$$

where R_{jt} is the vector of yields on seven government securities measured in months-to-maturity, T_j, where j equals 3, 6, 12, 30, 60, 120 and 240.[3/]

The J-test is implemented in the following manner: Suppose that equation (1) is assumed to be the null, and equation (3) is taken as the alternative. Further, it is assumed that equation (3) is not nested within equation (1), and vice-versa. To test the validity of the null hypothesis, the following equation is estimated:

$$(5)\quad \ln (M/P)_t = (1-\lambda)\,(\alpha_0 + \alpha_1 \ln y_t + \alpha_2 \ln T\,\text{bill} + \alpha_3 \ln(M/P)_{t-1})$$
$$\lambda(\ln(\widehat{M/P})_t) + \eta_t$$

where

$$(6)\quad \ln(\widehat{M/P})_t = \hat{\delta}_0 + \hat{\delta}_1 \ln y_t + \hat{\delta}_2 \gamma_0 + \hat{\delta}_3 \gamma_1$$
$$+ \hat{\delta}_4 \gamma_2 + \hat{\delta}_5 \gamma_3 + \hat{\delta}_6 \ln(M/P)_{t-1}$$

and where $\hat{\delta}_i (i = 0, 1,..., 6)$ are maximum likelihood estimates of equation (3).

The null hypothesis (equation (1)) is tested against the alternative (equation (3)) by testing the significance of λ in equation (5). Because the hatted coefficients are independent of the error term by assumption, a standard t-test can be used. Consequently, if the hypothesis that $\hat{\lambda} = 0$ cannot be rejected at a reasonable level of signifiance, equation (1) cannot berejected in favor of equation (3). If $\hat{g} \neq 0$, however, equation (1) is rejected in favor of equation (3). The test procedure then is reversed to differentiate between the competing models. The "true" model is assumed to be equation (3) which is tested against the alternative model, equation (1). If the null is rejected in both cases, however, the J-test is inconclusive.

3. EMPIRICAL RESULTS

Initial regression estimates for equations (1) - (3) corrected for serial correlation over the sample period I/1960-IV/1979 result in implausible coefficient estimates.[4/] To correct for this problem, a (0,1) intercept dummy equal to one from II/1974 onward and zero elsewhere is included in equations (1) - (3). The estimation results are presented in table 1.[5/] The explanatory power of each equation is high. The standard errors (SE) differ slightly, with the term structure equation reducing SE by 3 percent and 8 percent, compared with the T bill equation and the Bond equation, respectively.

The interest elasticities derived from the T bill and Bond equations are consistent with previous findings. The regression results from estimating the term structure money demand equation reveal that the estimated coefficient on the level (γ_0), slope (γ_1) and curvature (γ_2, γ_3) variables are significant at the 5 percent level. These coefficient estimates are consistent with the results of Heller and Khan (1979), Bilson and Hale (1980) and Allen and Hafer (1983). The coefficient on γ_0 indicates, for example, that a uniform 1 percent upward shift in the term structure reduces the demand for real M1 balances by 0.034 percent in the short-run. The coefficient on the estimated slope variable (γ_1) indicates that a one percent increase in the slope of the term structure (long rates exceeding short rates) will, ceteris paribus, reduce real money balances by 0.13 percent in the same quarter. The significant negative coefficients on the curvature variables (γ_2 and γ_3) suggest that greater curvature in the term structure, e.g., "humped-shaped" term structures, reduces the demand for real balances, ceteris paribus. Indeed, these results are consistent with Friedman's (1977) theoretical analysis.

Non-Nested Test Results

The discussion of the J-test assumes that the error terms are not serially correlated, but the estimates in table 1 are based on regressions that have been corrected for serial correlation. Pesaran (1974) suggests that under such conditions the J-test can be used if each model first is corrected for serial correlation. Unless the estimated serial correlation coefficients are equal, however, problems may arise. To avoid these problems, the following procedure was followed.[6/] Test A uses the estimated rho value from the null specification to estimate the test equation. Test B, on the other hand, uses the estimated rho value from the alternative equation. Although there should not be large differences between the t-statistics calculated using similar rho values, the sensitivity of the test to differences in rho is not known. Hence, we use both test procedures.

The estimate of λ and its corresponding t-statistic from applying the J-test to the possible pairs of money demand equations are presented in table 2. The results based on Test A indicate that, at the 10 percent level, the T bill and Bond specifications cannot be differentiated statistically. Comparing the T bill or Bond models to the term structure specification, however, reveals that each is rejected in favor of the term structure equation. The test statistics indicate that the T bill model is rejected at the 10 percent level, the Bond equation at the 5 percent level. The t-statistics calculated for the λ derived from reversing the test and using the term structure equation as the null hypothesis against the alternative T bill or Bond equations are equal to or less than one.

The results from Test B, where the rho value is taken from the alternative model, corroborate the Test A findings with respect to the usefulness of the term structure specification. Although these results clearly reject the T bill equation in favor of the Bond specification, both specifications again are rejected when compared to the term structure model. For the T bill/term structure comparison, the T bill model is rejected at the 5 percent level; for the Bond/term structure test, the level of rejection is raised to the 1 percent level. The t-statistics from the reversed tests are far below unity.

The J-test results provide statistical support for the use of the term structure model over the alternative models given by equations (1) and (2). Our results suggest that the information contained in a cubic specification of the term structure better captures the opportunity cost of holding money than does the use of the T bill rate or the Bond rate.

4. FORECAST RESULTS

In this section, the usefulness of incorporating the term structure in a money demand function is examined further by assessing the relative forecasting properties of each model. Since the appearance of Goldfeld (1976), a great deal of emphasis has been placed on out-of-sample forecasting as a means of judging the relative usefulness of one equation over another. Thus, the period from I/1980 to IV/1982 is used to compare post-sample forecasts generated by the alternative money demand equations.[7/]

The forecasting results presented in table 3 indicate that, irrespective of the equation used, relatively large forecast errors predominate.[8/] There is, however, an improvement in the forecasting results when the term structure specification is used. For instance, the mean error statistic for the term structure equation is more than 5 times smaller than that for either the T bill or Bond equation. The RMSE from the term structure model also is lower than the competing equations by about 8 percent.

Inspecting the forecast decomposition statistics, the term structure equation reduces the biasedness of the forecast errors by almost 100 percent when compared to the T bill and Bond equations. Indeed, relative to the other forecasts, most of the forecast error from the term structure equation can be attributable to unequal covariance between forecasted and actual real money balances. Thus, on the basis of forecasting performance, the evidence indicates that the term structure specification of money demand is preferrable to the single interest rate models.

5. CONCLUSION

A number of studies have sought to determine "the" appropriate interest rate in a money demand framework. Friedman (1977) has argued that a more viable approach to solving this dilemma may be to empirically estimate the position and shape of the term structure of interest rates and to enter this information directly into a money demand function.

The non-nested test procedure of Davidson and MacKinnon (1981) was used to statistically assess the importance of incorporating the term structure information in a money demand function. Compared to specifications that use a short-term or long-term rate, the term structure specification was preferred. Although there was mixed evidence about the relative superiority of the T bill and Bond models, in every test the term structure specification could not be rejected at the 5 percent significance level. Moreover, out-of-sample forecast comparisons revealed that again the term structure model provided, on average, more accurate predictions relative to the alternative specifications. Thus, based on the evidence presented in this study, the term structure specification of money demand clearly deserves the further attention of researchers.

FOOTNOTES

1/ Recent exceptions are McAleer, Fisher and Volker (1982) and Thornton (1983). Each study uses annual data. Moreover, Pesaran (1982) has shown using Monte Carlo estimates that the orthodox F-test procedure is a weaker test relative to non-nested tests when the sample is greater than twenty and the number of non-overlapping variables between the competing specifications is greater than one.

2/Goldfeld (1973, 1976); Enzler, Johnson and Paulus (1976); and Boughton (1981) use similar specifications.

3/ Comparison of quadratic and cubic models of the term structure is made in Allen, Hatfield and Williams (1981). Results by Allen and Hafer (1983) suggest that the cubic specification is preferable.

4/ Heller and Khan (1979), Khan (1980), Bilson and Hale (1980) and Allen and Hafer (1983)) use either the Cochrane-Orcutt or the Hatanaka (1974) procedure. Offenbacher (1981) has examined the properties of these two procedures, along with a maximum likelihood estimation. Based on his findings, we employ a maximum likelihood-grid search technique of .01 increments to correct for serial correlation. Qualitatively similar results are obtained by the Beach-MacKinnon maximum likelihood estimation procedure. Stopping the sample in IV/1979 allows comparisons of the alternative models' post-sample forecasting capabilities. (See Section 4.)

5/ The dummy (D1) coefficient is positive and highly significant, indicating a downward displacement of each equation in early 1974 (see table 1). A similar term is used by Hafer and Hein (1982) and Brayton, Farr and Porter (1983) to account for (but not explain) the 1974 shift. For a review of the empirical work attempting to explain the apparent shift of the function, see Judd and Scadding (1982).

The importance of this term was examined further by comparing the stability of each equation with and without the dummy variable. Based on a standard Chow test, the null hypothesis of stability is rejected easily (5 percent level) when the dummy term is excluded. The relevant F-statistics are: T bill equation -- $F(4,71) = 2.51$; Bond equation -- $F(4,71) = 6.07$; and the term structure equation -- $F(7,65) = 2.51$. When the shift-term is included, however, the null hypothesis cannot be rejected: T bill equation -- $F(3,72) = 0.29$; Bond equation -- $F(3,72) = 2.52$; and term structure equation -- $F(6,64) = 0.27$.

6/ This approach also is used in Thornton (1983).

7/ Based on the analysis of Hein (1982), static forecasts are compared.

8/ The evidence of large forecasting errors found in table 4 does not, however, provide evidence of recent money demand shifts. If a "shift" in the relationship occurred during the forecast period, the forecast errors would appear one-sided. The evidence in table 4 indicates that one-sided errors are not the problem. The large forecast errors found in table 4 are associated with large swings in nominal money stock growth. The association between rapid, sharp changes in the growth of the nominal money stock and large forecast errors generated by money demand models is investigated in Carr and Darby (1981), Judd and Scadding (1981), Khan and Knight (1982) and Coats (1983).

Table 1
Money Demand Regression Results: 1960/I - 1979/IV

Coefficient	Specification: T bill	Bond	Term Structure
Constant	-0.462 (6.36)	-0.523 (5.36)	-0.542 (6.99)
D1	0.021 (5.46)	0.017 (3.39)	0.017 (3.98)
$\ln y_t$	0.090 (6.06)	0.107 (5.40)	0.104 (6.75)
$\ln \text{T bill}_t$	-0.017 (4.97)		
$\ln \text{Bond}_t$		-0.032 (3.10)	
γ_0			-0.034 (3.93)
γ_1			-0.130 (2.37)
γ_2			-0.750 (2.20)
γ_3			-4.501 (2.14)
$\ln(M/P)_{t-1}$	0.815 (16.87)	0.781 (12.53)	0.828 (17.65)
$\bar{R}^2$	0.991	0.990	0.991
$SE(x10^{-3})$	4.594	4.848	4.447
Dh	0.764	1.064	0.719
$\hat{\rho}$	0.27 (2.21)	0.41 (3.22)	0.25 (2.06)

Table 2
J-test Results
Sample Period: 1960/I - 1979/IV

Test A1/

Null/Alternative	λ	t-ratio
T bill/Bond	0.491	1.88***
Bond/T bill	0.421	1.90***
T bill/Term Structure	0.645	1.96***
Term Structure/T bill	0.248	0.51
Bond/Term Structure	0.533	2.36**
Term Structure/Bond	0.424	0.90

Test B1/

Null/Alternative	λ	t-ratio
T bill/Bond	0.267	1.11
Bond/T bill	0.735	3.36*
T bill/Term Structure	0.707	2.10**
Term Structure/T bill	0.181	0.40
Bond/Term Structure	0.886	3.88*
Term Structure/Bond	0.060	0.21

1/ Test A uses $\hat{\rho}$ from Null specification.

2/ Test B uses $\hat{\rho}$ from Alternative specification.

*significant at 1 percent level.
**significant at 5 percent level.
***significant at 10 percent level.

Table 3
Post-Sample Forecasting Results
Period: I/1980-IV/1982
(real money balances, billions of dollars)

		Specification/Forecasts		
Period	Actual	T Bill	Bond	Term Structure
I/1980	$228.66	$229.53	$230.13	$228.76
II	221.03	228.79	228.85	228.10
III	224.66	222.83	222.72	221.99
IV	224.29	224.48	225.04	223.50
I/1981	221.23	224.35	224.91	223.28
II	222.48	221.64	222.02	220.48
III	219.46	222.73	222.61	221.40
IV	216.62	220.94	220.11	219.45
I/1982	220.02	218.02	217.51	216.48
II	219.29	221.03	220.56	219.70
III	219.96	221.56	220.45	220.77
IV	225.09	222.68	222.25	222.08
Summary Statistics:				
Mean Error:		$1.32	$1.20	$-0.27
Mean Absolute Error:		$2.50	$2.49	$2.27
RMSE:		$3.16	$3.16	$2.89
Theil U:		0.014	0.014	0.013
Bias:		0.174	0.144	0.008
VAR:		0.0001	0.011	0.004
COV:		0.826	0.845	0.987

REFERENCES

Allen, S.D. and R.W. Hafer, 1983, Money Demand and the Term Structure of Interest Rates: Some Consistent Estimates, _Journal of Monetary Economics_ (January), 129-32.

__________, B. Hatfield and D.A. Williams, 1981, A Cubic Estimate of the Term Structure of Interest Rates for a Money Demand Function, _Journal of Macroeconomics_, Winter, 91-96.

Bilson, J.F.O. and R.S. Hale, 1980, Further Evidence on the Term Structure of Interest Rates and Money Demand, Report No. 8001, Center for Mathematical Studies in Business and Economics, University of Chicago, (January).

Boughton, J.M., 1981, Recent Instability of the Demand for Money: An International Perspective, _Southern Economic Journal_ (January), 579-97.

Brayton, F., T. Farr and R. Porter, 1983, Alternative Money Demand Specifications and Recent Growth in M1, Federal Reserve Board (processed).

Carr, J. and M.R. Darby, 1981, The Role of Money Supply Shocks in the Short-Run Demand for Money, _Journal of Monetary Economics_ (September), 183-99.

Coats, W.L., 1982, Modeling the Short-Run Demand for Money with Exogenous Supply, _Economic Inquiry_ (April), 222-39.

Davidson, R. and J.G. MacKinnon, 1981, Several Tests for Model Specifications in the Presence of Alternative Hypotheses, _Econometrica_ (May), 781-93.

Enzler, J., L. Johnson and J. Paulus, 1976, Some Problems of Money Demand, _Brookings Papers on Economic Activity_ (1), 261-80.

Feige, E.L. and D.K. Pearce, 1977, The Substitutability of Money and Near Monies: A Survey of the Time-Series Evidence _Journal of Economic Literature_ (June), 439-69.

Friedman, M., 1977, Time Perspective in the Demand for Money, _Scandanavian Journal of Economics_ (4), 397-416.

__________ and A.J. Schwartz, 1982, The Effect of the Term Structure of Interest Rates on the Demand for Money in the United States, _Journal of Political Economy_ (February), 201-12.

Goldfeld, S.M., 1976, The Case of the Missing Money, _Brookings Papers on Economic Activity_ (3), 683-730.

Hafer, R.W. and S.E. Hein, 1982, The Shift in Money Demand: What Really Happened? Federal Reserve Bank of St. Louis _Review_ (February), 11-16.

Hatanaka, M., 1974, An Efficient Two-Step Estimator for the Dynamic Adjustment Model with Autoregressive Errors, Journal of Econometrics (September), 199-220.

Hein, S.E., 1980, Dynamic Forecasting and the Demand for Money, St. Louis Federal Reserve Bank Review (June/July), 13-23.

Heller, H.R. and M.S. Khan, 1979, The Demand for Money and the Term Structure of Interest Rates, Journal of Political Economy (February), 109-29.

Judd, J.P., and J.L. Scadding, 1981, Liability Management, Bank Loans and Deposit "Market" Disequilibrium, Federal Reserve Bank of San Francisco Economic Review (Summer), 21-44.

__________ and __________, 1982, The Search for a Stable Money Demand Function, Journal of Economic Literature (September), 993-1023.

Khan, M.S., 1980, The Term Structure of Interest Rates in Money Demand Models: A Further Analysis, Economics Letters (3), 261-66.

Khan, M.S. and M.D. Knight, 1982, Unanticipated Money Growth and Inflationary Finance, Journal of Money, Credit and Banking (August), 347-64.

Laidler, D.E.W., 1977, The Demand for Money, 2nd. ed. (New York: Dun-Donnelley).

McAleer, M., G. Fisher and P. Volker, 1982, Separate Misspecified Regressions and the U.S. Long-Run Demand for Money Function, Review of Economics and Statistics (November), 572-83.

Offenbacher, E.K., 1981, Two Papers on Money Demand, Special Studies Paper No. 157, Federal Reserve Board (July).

Pesaran, M.H., 1974, On the General Problem of Model Selection, Review of Economic Studies (April), 153-172.

__________, 1982, Comparison of Local Power of Alternative Tests of Non-Nested Regression Models, Econometrica (September), 1287-1306.

Thornton, D.L., 1983, On the Appropriate Interest Rate and Scale Variable in Money Demand: Some Results from Non-Nested Tests, Working Paper No. 83-006, Federal Reserve Bank of St. Louis.